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Project Report

A Mixed Method Study to Explore How Maintenance Personnel Can Enhance Wildfire Smoke Resilience at Long-Term Care Facilities in the US Mountain West

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Abstract: Wildfire activity is increasing around the world, concurrent with climate change, and mitigation strategies for protecting vulnerable populations are desperately needed. Because inhaled particles are deleterious to respiratory health, particularly among older adults with co-morbidities, we engaged maintenance personnel working in long term care facilities located in the Western US. Our objective was to identify opportunities to build resilience during wildfire smoke events. We implemented a virtual workshop that addressed wildfire smoke health impacts as well as strategies to assess and maintain indoor air quality. A total of 24 maintenance personnel attended the virtual workshop and 14 participated in a quantitative survey. Workshop attendees found value in the material and there was enthusiasm for educational resources and enhancing indoor air quality. Four months later, four maintenance staff participated in a follow-up interview. Our qualitative assessment revealed the following themes: awareness and prioritization, application of knowledge, barriers, and educational resources. Access to real-time actionable air quality data was a consistent feature across these themes. Maintenance personnel could play a key role in a facility's ability to prepare for and respond to wildfire smoke events, and this study highlights potential challenges and opportunities to involving them in resilience building strategies.

Keywords: indoor air pollution; elder health; wildfire smoke; climate change; resilience

Citation: Arok, A.; Caringi, J.; Toevs, S.; Spivak, M.; Montrose, L. A Mixed Method Study to Explore How Maintenance Personnel Can Enhance Wildfire Smoke Resilience at Long-Term Care Facilities in the US Mountain West. *Atmosphere* **2024**, *15*, 504. https://doi.org/10.3390/atmos15040504

Academic Editor: Parinaz Poursafa

Received: 20 February 2024
Revised: 10 April 2024
Accepted: 18 April 2024
Published: 20 April 2024

1. Introduction

Wildfires are becoming more frequent and destructive, concurrent with climate change [1–4]. Smoke emitted from wildfires can affect large populations, even communities distant from the fires, by degrading air quality at the local, regional, and global scales [5]. Such transient smoke effects were particularly evident during the 2023 Canadian wildfires, where smoke was directed southward to the Midwest and Northeastern US by coastal storms [6]. Wildfire smoke is a complex mixture of gasses and particles, yet concentrations of fine particulate matter ($PM_{2.5}$) are commonly used as a proxy measurement for the mixture because it is a dominant constituent in smoke and it has known deleterious impacts on the lower airways [7,8]. Wildfire smoke can increase $PM_{2.5}$ levels to several times those seen during non-wildfire periods [4,9]. These exposure sources and regimens are unique to the Western US and are different to other parts of the US that have experienced improved ambient air quality due to prudent regulations [8,10]. There is clear evidence that air pollution causally impacts all-cause, cardiovascular, and respiratory morbidity and mortality [11–20]. With the backdrop of a changing climate and an aging population, it is imperative to mitigate the associated health burden of wildfire smoke [3].

Today, there are nearly 50 million US adults over the age of 65, and this number is projected to double by 2060 according to a report by the Population Reference Bureau [10].

It is estimated that the number of Americans accessing long-term care services will also double during this period of time [11]. While the number of individuals living past 65 is increasing, it is notable that these older adults are not necessarily healthier. According to a 2022 report by the McKinsey Health Institute, the global life expectancy over the last six decades has increased by almost 20 years and yet the amount of time spent in moderate to poor health has remained consistent [12]. Moreover, with more focus on support and services to help people age in place, many who enter long term care (LTC) facilities are sicker and thus more vulnerable by the time they can no longer remain at home. This has important economic implications for our healthcare system and demands that we identify solutions to improve health later in life [12,13].

The COVID-19 pandemic, in combination with increasing evidence linking ambient $PM_{2.5}$ with adverse respiratory health effects, has heightened our awareness of indoor exposures [14,15]. This is especially important given people spend up to 90% of their time indoors in the US, and this percentage is likely higher among older adults [16,17]. Our team has recently demonstrated that ambient air infiltrates the indoor space at a skilled nursing facility (SNF) and indoor air quality (IAQ) is especially diminished during a wildfire smoke event [18]. In industrialized countries, about 20% of those above 85 years old and 5% of those above 65 years old are nursing home residents [19,20]. SNFs are LTC facilities that provide care for the elderly from trained registered nurses, and residents tend to have higher rates of cardiopulmonary comorbidities [19]. Thus, the SNF environment is of particular interest in the context of IAQ.

Due to the elderly population's reduced immune systems, it would be prudent for LTC facilities to be designed, constructed, and maintained in order to provide adequate living conditions for the most vulnerable within the resident population [21]. The purpose of building ventilation and air conditioning systems is to create IAQ more suitable for people relative to ambient air quality [22]. The adequate operation of building systems, including heating, ventilation, and air conditioning (HVAC) equipment, as well as providing for a tight building envelope, can reduce the risk of respiratory morbidity and mortality [22,23]. Maintenance personnel likely play a key role in maintaining building conditions and thus could help improve the IAQ for inhabitants of commercial building spaces, particularly LTC facility residents.

While the health effects of indoor air pollution have been well documented, specific strategies to enhance IAQ and build resilience among older adults are limited. There is a critical gap in understanding the role that maintenance workers can play in improving IAQ to protect resident health in the LTC facility environment. This research focuses on the development of strategies to educate through outreach and identify ways that maintenance personnel can enhance IAQ for the benefit of facility residents. Here, we will discuss the exploratory strategies that were tested as well as the preliminary quantitative and qualitative data that were collected to measure the impact of these strategies.

2. Materials and Methods

2.1. Participants and Recruitment

Wildfire smoke impacts downwind communities, in particular LTC facility residents. However, the residents have limited control of the indoor conditions. Rather, facility maintenance personnel play a central role in operating and maintaining systems (e.g., HVAC) that influence indoor conditions. Thus, maintenance personnel in LTC facilities were the target audience for the online workshop and surveys. To reach potential attendees, we partnered with the Health Care Associations of Montana and Idaho. The workshop registration information was posted on the Health Care Associations' web pages under a training and education tab and a total of three emails were sent to maintenance personnel from the Health Care Associations on our research team's behalf. Recruitment for the post-workshop key informant interview was completed by our research team using a contact list generated from those maintenance personnel who registered for the online workshop. We employed both email and phone calls to reach potential participants.

2.2. Online Workshop Description and Delivery

The workshop presentations were designed to address three major themes, including (1) wildfire smoke and health, (2) strategies that are used to assess indoor air quality, and (3) maintenance of indoor air quality. Complimenting these themes, the following learning objectives (LO) were developed: (LO1) to gain a general appreciation for the health effects of air pollution from sources like wildfire smoke, (L02) to recognize common issues that lead to poor indoor air quality within LTC facilities, and (3) to become aware of resources and strategies for improving indoor air quality. The workshop was delivered on 8 December 2021 via Zoom Webinar and lasted 90 min.

2.3. Online Workshop Survey

Quantitative survey questions (see Supplemental Document) were focused on three major themes, which included demographic information, baseline knowledge, and plans for the application of knowledge. Survey questions were developed by an interdisciplinary group of researchers, including an environmental toxicologist, a mixed methods research expert, an emergency preparedness specialist, an industrial hygienist, and representatives from the Idaho Health Care Association. The questions included Likert scale multiple choice options and 'select all that apply' from lists generated by our research team. To avoid survey fatigue and to fit into the workshop timeline, we condensed the initial list of questions to ten. At the beginning of the workshop, before the three speakers presented, we deployed five questions for the maintenance workers to answer. The questions were integrated into the Zoom platform. Participants were given approximately two minutes to answer the questions. After the allotted time, the results of the questions were displayed and briefly discussed. Following the presentations from all three speakers, questions 6–10 were deployed. Similar to the first set of questions, participants were given approximately two minutes to answer the questions and after the allotted time the results of the questions were displayed and briefly discussed.

2.4. Post-Workshop Key Informant Interviews

The purpose of these interviews was to understand the impact of the initial online workshop from maintenance personnel who participated. The qualitative questions (see Supplemental Document) were designed to gain further insight into the value of the workshop to the participants, whether participants applied any of the knowledge gained, and if any barriers were encountered. Five open-ended questions were developed by an interdisciplinary group of researchers including an environmental toxicologist, a mixed methods research expert, and graduate students.

Two interview sessions were conducted approximately four months after the December 2021 online workshop, on 25 and 26 April 2022. Participants were given the choice to attend either session. Three participants attended the first session and one participant attended the second session. The interview was hosted via Zoom for a total of 30 min per session. Each interview had a facilitator and two other researchers in addition to the participants. The facilitators asked the prepared questions and allowed time for each of the participants to provide their feedback. The recorded sessions were transcribed and de-identified by a study team member and then checked for accuracy by a second team member.

2.5. Analysis Strategy

Data collected during the workshop included answers to quantitative questions. These data were tabulated and presented as descriptive statistics. For the qualitative data collected during the post-workshop interviews, we used a grounded theory inductive approach to assess the responses [24]. As this is an exploratory study and the first of its kind, this was the most appropriate method of analysis [25]. First, two study team members independently coded the transcripts and noted themes of responses that they observed. These team members then generated narrative summaries of the categories and presented these to each other along with a mixed methods expert. Interview data were analyzed using qualitative content analysis. This method is useful for specifying categories and recognizing common concepts [26,27]. The research team first identified factors in coding. A code book was developed and reviewed as the analysis progressed to ensure accuracy. Factors were then grouped into categories. Using the Deterding and Waters coding method, interview data were assessed [28]. The three team members reviewed the categories individually and developed initial themes. The team then reviewed the proposed themes together and revised them until there was a consensus list of themes, which are described in the Results section. All qualitative data for the study used the Standards for Reporting Qualitative Research (SRQR) for reporting [29]. The Boise State University Human Subjects Institutional Review Board provided review and approval of all study components (protocol number 186-SB21-118).

3. Results

3.1. Online Workshop Outcomes

Recruitment for the online workshop resulted in a total of 56 registrants, of which 34 were from Idaho, 22 were from Montana, 1 was from Washington, and 1 wrote "other". Of the 56 initial registrants, a total of 34 participants signed up to the Zoom event. According to the intake information captured during registration, out of the total 34 participants who attended, 24 (71%) were facility maintenance workers, followed by administrators (20%) and then academic faculty (9%).

3.2. Online Workshop Survey Question Findings

At the beginning of the workshop, participants were again asked about their role in LTC facilities. Of the 19 who responded to the real-time survey question, 14 (74%) were facility maintenance workers. Of those LTC facility maintenance workers, 58% worked in skilled nursing facilities and 42% in assisted living. Of those same 14 maintenance workers, a majority reported being in their roles for more than four years (57%) and only one had been in their role for less than a year. When asked where the LTC maintenance workers receive HVAC-related training, 14 responded and all of them reported getting on-the-job training, and only one reported also attending a relevant trade school. Regarding their self-reported HVAC skill level, 10 out of 14 respondents said they were either slightly confident or fairly confident, with the other 4 being either mostly confident or completely confident.

At the end of the workshop, participants were asked if the information presented would help them perform their job more effectively, and 19 out of 20 strongly or moderately agreed. When asked to consider if the workshop would change the way they prioritized air quality during the wildfire season, 18 out of 20 either strongly or moderately agreed. Our study team recognizes there may be barriers to becoming smoke resilient. When asked what barriers the maintenance workers could anticipate, they reported time (7 out of 20), money (13 out of 20), and manpower (4 out of 20) most often. A smoke readiness plan—a formal written designation of response actions and involved personnel—was discussed in the workshop. When asked how likely their LTC facility was to establish and implement a smoke readiness plan, there was a broad distribution in responses, with slightly more than half responding most likely or very likely, and slightly less than half responding only fairly likely or slightly likely. The final end-of-workshop question asked what was one thing the maintenance workers planned to change at their facility relating to wildfire smoke and indoor air quality. Given multiple options and the ability to select all that applied, the most common responses were related to checking building pressure (8 out of 20), ensuring good filter fitment (8 out of 20), and upgrading the filter type during wildfire season (13 out of 20).

3.3. Post-Workshop Key Informant Interview Outcomes

Recruitment for the interviews resulted in the participation of a total of four LTC facility maintenance personnel from Idaho and Montana. The interviews took place in two 30 min sessions, where session one had three participants and session two had one participant. After the sessions were transcribed, coded, and analyzed, four themes emerged: (1) awareness and prioritization of indoor air quality, (2) application of new knowledge, (3) barriers to implementation, and (4) educational resources.

3.3.1. Theme 1: Awareness and Prioritization of Indoor Air Quality

Participants who were interviewed stated that the workshop was a positive experience that raised their awareness and appeared to change their perspectives about the impact of smoke on residents at LTC facilities. Participants made connections between materials presented at the workshop and their own facilities. Further, they felt that their knowledge of IAQ was enhanced and that IAQ would become a higher priority for their facilities, especially during wildfire smoke season. Prior to the workshop, participants suggested they were unfamiliar with the health impacts of poor indoor air quality and its concerning effects. Participants also noted differences in their perception that indoor air was always clean, with one mentioning that they were previously unaware of the connection between outdoor and indoor air quality. Specifically, one participant said:

> "I definitely had an enhanced perspective of how the indoor air quality was different and sometimes even worse than the outdoor air quality and the sense that I felt like I had a bit more protection indoors versus outdoors and came to realize that I needed to enhance the kind of filtration in order to protect the residents"

Participants tended to agree that the information presented at the workshop changed the way they were prioritizing IAQ for the upcoming wildfire season. They expressed concerns for the residents in their facilities and felt that the smoke during past wildfire seasons increased the level of stress and other health risks for the residents. One participant made a connection with their personal health status, stating that:

> "As I have allergies myself and the smoke actually bugs me, you know, it opened my eyes a little bit to see and make sure we're doing all we can to help keep it out".

The other participants in this session agreed and expressed concerns for the residents in their facilities that have similar pre-existing health conditions. Participants also recognized that the demographics of their resident population were important to consider in the context of poor air quality, with one stating that:

> "We have a vulnerable population and keeping them safe is my number one priority"

One participant added that the health concerns of poor IAQ extend beyond those with pre-existing health conditions and affect individuals who do not have health problems. Awareness of the negative health impacts for some participants motivated them to consider how to keep better track of the indoor air quality, with one participant saying:

> "It was a great workshop, it really opened up my eyes to the need for monitoring our indoor air quality to keep the residents safe".

3.3.2. Theme 2: Application of New Knowledge

Participants reported that they were willing to take action after the workshop. We found that between the time of the workshop and the interview, they set goals to improve IAQ in their facilities and many reported optimism for making future improvements in IAQ during wildfire season. For example, some participants made goals to change filters more frequently during the wildfire season relative to non-wildfire periods. One participant discussed their intention to change filters at regular intervals as a precaution rather than when filter material "looked dirty". Others in the session agreed that you cannot always tell if a filter is dirty just by its appearance. Participants also applied the knowledge gained from the workshop in the form of building tours, HVAC system checks, communication with experts, and smoke planning. One participant mentioned that they assessed their facility's air filter systems to make sure they were "sealed, secured and operating properly".

Participants reported that they would try to do simple things like making sure that windows and doors are closed properly during smoke season. The maintenance personnel who participated in the workshop went back to their facilities and communicated and shared knowledge with additional LTC staff through training sessions and monthly staff meetings. One participant reported that they planned to communicate with staff regarding indoor air quality via texting, while another stated:

> "So at least as far as what I can do from a maintenance perspective would be to educate both residents in person, as well as putting notices on doors".

Participants became more knowledgeable about the importance of filter material as it relates to air pollution mitigation. Regarding minimum efficiency rating values (MERV) and recommendations for healthcare settings, one participant reported that they were running MERV 8 filters but made the switch to the recommended MERV 13 following the workshop. This prompted another participant to state:

> "My goal may have just changed from the insights that [participant 3] brought forward. I guess, I assumed my system could handle MERV 13 but I might have to assess whether or not I've got enough pressure. So my goal was to get those filters for fire season, and I might have to do just a little verification first".

Other participants discussed concerns that even MERV 13 filtration alone may not be sufficient to protect residents during wildfire season. After attending the workshop, participants reported that they were better prepared to conduct job duties particularly related to filter maintenance. One anecdote related described a staff member who tried to modify filters that were not designed for their facility's HVAC system, but after the workshop had an HVAC expert make sure they were using correct filters.

In addition to filtration, participants were interested in engaging in air quality monitoring activities at their facilities. There was a collective agreement that access to these data would help to determine when staff and residents are at higher risk of inhaling poor air.

3.3.3. Theme 3: Barriers to Implementation

Maintenance staff reported that they felt that addressing indoor air quality challenges in the short term is a worthwhile investment and that these goals were generally a priority of their upper management. However, upper management support for mitigating the risks of poor indoor air quality was not equal based on the participant responses. For example, following the workshop some facility managers were willing to allocate funds towards purchasing air filters to allow for more frequent filter change-outs, while other managers would not change budget allocations to address indoor air quality risk.

> "On my side of things, I don't get any pushback on with ordering filters or anything, pretty much you know, it's something that has to be done. My administrators understand that and you know when I need them, I order them".

> "My facility is going through changes and just one of the owners is having to cover a lot of the expenses out of her own pocket. So if I was to request anything, it's kind of usually put in a holding pattern and maybe readdress down the road".

Other barriers to air quality management were staffing turnover or shortages, continuity and communication between staff, lack of compliance from residents, and lack of funding or expertise. The participants also pointed to a lack of indoor air quality data and lack of access to building- or HVAC-specific information. Some participants noted that their facilities lacked the resources to make capital investments in high value equipment such as new HVAC systems. Importantly, without such investment, some facilities cannot upgrade filtration to the recommended MERV 13 filter material. Similarly, other participants reported a lack of funding for sophisticated HVAC system monitoring equipment that is standard in newer healthcare buildings. Participants also discussed observed and anticipated challenges with facility staff compliance related to building envelope tightness, with one stating:

> "The hardest part of that is getting staff on board with actually keeping windows shut and not holding the doors open and stuff"

Of note, several participants mentioned that the COVID-19 pandemic had affected facility operations and increased turnover. One maintenance personnel said that COVID-19 had "pretty much liquidated a bunch of our staff", making communication difficult. Another interview participant said that representatives from the Occupational Safety and Health Administration (OSHA) had come to their facility and "put out a bunch of mandates for your HVAC system". Some of these mandates conflicted with local government recommendations for wildfire smoke response. Participants noted that the COVID-19 pandemic had a direct impact on their ability to implement knowledge gained at the workshop, particularly due to budget cutbacks.

Interestingly, some participants noted that they perceived an IAQ improvement in their facilities from changes made after the workshop, but observed that without monitors, they had no way to actually know. As this discussion continued, many participants agreed that this would be a major benefit of having air monitors installed at their facilities. One stated that:

> "If there is any way for me to have a metric to follow to know when there's maybe a higher risk or something that I could track locally from in house here, that would be amazing".

3.3.4. Theme 4: Educational Resources

The interview participants consistently reported that they found the educational materials from the workshop meaningful. They reported that the workshop presenters were a trusted resource and desired continued engagement with this topic, expressing interest in future workshops and events. One participant noted that:

> ". . .the workshop is something you should reread and go back through just so you can totally comprehend it".

Another participant mentioned that they were contributing a lot of individual effort at their facility and expressed that "I feel like I am a one man show". However, the workshop "gave him direction" as well as made him feel more confident in his role and that he was part of "something bigger". This participant went on to say:

> "A [workshop] happening that was able to help me digest some of this stuff, guide me in the right direction, and actually left me really thirsty for more".

When asked how the workshop could be improved, one participant reported a desire to see more data in the form of graphs and other visuals describing the effects of IAQ in their facilities. To spread the knowledge to more staff at their facility, participants suggested that it would be beneficial to have air monitors in their facilities and to collect data to show the other staff, and that this may help staff to comply with messages about closing windows and doors.

Participants also demonstrated an interest in future educational activities. One stated that he wanted to "dig deeper" into similar topics on wildfire smoke and health, while another wanted to further engage in the topic by having smoke readiness planning events, stating:

> "With me, I think that formalized smoke plan is actually a good idea, because then you know you might have some buildings out there that don't have a clue. And something a little more formal would help them along the ways of understanding and how much importance and priority, this should be".

Not all wanted that level of initial engagement, but rather wanted to create a smoke readiness plan on their own and then have experts review it. One participant said:

> "I like the idea of having a zoom call with the suggestions, maybe we could outreach to those professionals as like a homework assignment and come back and maybe present this new management plan".

4. Discussion

The adverse health effects of indoor air pollution have been well documented in the general population. While less is known about the impact of IAQ on the health of older adults, available data suggest that poor IAQ is associated with adverse elder respiratory health [16]. With the backdrop of increased wildfire activity in the Western US, this exploratory study suggests that LTC maintenance workers can play an important role in maintaining and improving the IAQ. Here, we found that an online 90 min workshop, which was supported by regional health care associations, enhanced maintenance workers' awareness and prioritization of IAQ. This was demonstrated by data collected during the workshop and reaffirmed in the follow-up interviews. Additionally, the participants in the follow-up interview noted that they implemented multiple low-cost strategies learned in the workshop. Access to real-time actionable data was a consistent feature throughout our four identified qualitative themes. Importantly, the participants raised the point that air monitoring data was necessary to prompt changes in normal facility practices, assess the effectiveness of any changes that are implemented, and convince other staff of the importance of IAQ and its direct connection with ambient conditions.

Participants who attended the workshop and were later interviewed should be viewed as especially engaged in the topics of IAQ, wildfire smoke, and LTC resident health. However, they still reported significant barriers to implementing suggestions from the workshop. During the workshop, speakers were asked to focus on a full range of remedies, from low-cost to major capital investment, understanding budgetary constraints across the industry. Participants still reported that low-cost solutions were met with pushback by facility administrators. Maintenance workers also suggested that a high turnover of LTC staff influenced the sustainability of knowledge and progress towards improving IAQ. This was exacerbated by the COVID-19 pandemic, according to the participants.

The opportunities and challenges identified here can inform future projects aimed at protecting LTC facility residents. Individuals in LTCFs are typically older adults, often with multiple comorbidities and limited mobility [11], making LTCF residents particularly susceptible to elevated air pollution exposure. There is a substantial quantity of works in the literature describing the associations between air pollution exposure and older adults [30–38], as well as a growing body of literature on the impacts of wildfires on older adults. In response to the increasing threat of wildfires in the Mountain West, the Journal of the American Medical Association recently published an assessment on nursing home preparedness and responsiveness to wildfires [39–41]. This report demonstrates that LTCFs most at risk for wildfire impacts were often the least prepared, evidenced by the number of critical emergency preparedness deficiencies cited during CMS inspections. Compared to other regions, facilities in the Mountain West had the strongest association between wildfire risk and number of emergency preparedness deficiencies, highlighting the need for improved responses in the target area of our study [39].

A long-term goal of this study is to improve perceptions, attitudes, and behaviors related to the protection of IAQ during wildfire smoke events. The importance of building maintenance and operations, and the role of facility managers and maintenance personnel in protecting IAQ, have been documented [42,43], particularly for hospital systems and elderly populations in public housing [44–46] While aspects of a facility such as design, ventilation, envelope, and maintenance are factors that affect IAQ [47], little is known about the knowledge and perceptions of maintenance workers on IAQ and their role in protecting IAQ during wildfire smoke events.

Studies conducted among the general public may be informative for assessing IAQ education and outreach effectiveness. One study by Kencanasari et al. conducted educational workshops on the importance of IAQ in Indonesia and found a moderate increase in public awareness in terms of knowledge, attitudes, and actions [48] The authors found that study participants generally recognized negative effects of poor air quality but lacked knowledge of the components that could improve air quality. Similar to this study, maintenance workers in our study had a general understanding of the impacts of poor air quality but did not necessarily understand what aspects of their job could contribute to improving poor IAQ.

Air quality monitoring was also emphasized by the interview participants in our study, but this is not a commonly used tool based on our interactions with facilities in Idaho and Montana. We have previously demonstrated the utility of deploying hyperlocal real-time monitors in LTC facility settings [18]. Others have also shown the potential for using low-cost monitors over extended periods to assess the outdoor to indoor infiltration of air pollution. Jones et al. deployed indoor monitors in 37 office buildings in four countries, and their results suggest that ventilation and filtration are protective strategies for reducing exposure during ambient pollution events [49]. Nguyen et al. investigated a single health care building during a two-month period of the 2020 wildfire season, where they deployed two outdoor and seven indoor monitors [50] Their results indicate that $PM_{2.5}$ infiltrates the indoor space to a greater degree during a smoke event and is variable by location within the building. While these tools are demonstrably useful in assessing risk, we recognize that these devices may still be cost-prohibitive for some facilities and that the interpretation of the data for decision making may be problematic without consultation with an air quality specialist.

This exploratory study addresses a pressing public health issue for a vulnerable population in a novel way through engagement with key LTC facility staff. However, it was not without limitations. The sample size for the key informant interviews was particularly limited. With a small sample size, the risk of sampling bias is higher and may not be representative of the maintenance workers that attended the workshop or the broader population of maintenance workers in LTC facilities across the Western US. Another limitation that may have impacted our study's generalizability is the lack of geographic diversity in the sample. Our population represented maintenance workers from Idaho and Montana and may not reflect all the LTC facilities impacted by wildfire smoke. In this study, we did not conduct a formal pre/post assessment to quantify knowledge gained from the workshop. Therefore, interpretation of the post workshop survey responses is limited. Finally, we acknowledge that for this trial we did not perform formal validity or reliability testing of our questions with members of our target population. However, we did work with members of the LTC community to review and revise the content.

Overall, this novel exploratory study demonstrates the potential for maintenance personnel in the LTC setting to aid in the protection of vulnerable resident health through the enhancement of the IAQ. This is important given the current and anticipated wildfire activity in the Western US and in many other parts of the world. Maintenance personnel who participated in the study were enthusiastic about building resilience at their facility and helped to identify opportunities for implementing budget-friendly solutions as well as likely barriers that need to be addressed moving forward. Low-cost monitors are highlighted as a tool that LTC facilities could benefit from, but cost and interpretation may hinder their widespread use.

Future research aimed at assessing exposure risk and mitigation to poor indoor air quality and respiratory diseases in the LTC setting needs to focus on several key areas. First, future research should identify specific sources and types of indoor air pollution that are most harmful to the respiratory health of the elderly and explore potential interventions and policies aimed at reducing exposure to these pollutants. Another important area for future research is the development and validation of new tools and technologies for measuring and translating IAQ, particularly in LTC facilities and other settings where elderly populations may be at increased risk for exposure to poor air quality events. These tools could be incorporated into a comprehensive wildfire smoke readiness plan aimed at enhancing LTC facility resilience to smoke events. Future studies can also investigate the role that different staff (e.g., infectious disease nurses, administrators, or maintenance workers) play in improving IAQ in LTC facilities.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/atmos15040504/s1.

Author Contributions: Conceptualization, L.M. and A.A.; methodology, J.C. and S.T.; formal analysis, L.M., J.C. and A.A.; investigation, L.M. and A.A.; data curation, A.A.; writing—original draft preparation, A.A.; writing—review and editing, L.M., J.C., M.S. and S.T.; supervision, L.M. and J.C.; project administration, M.S.; funding acquisition, L.M. All authors have read and agreed to the published version of the manuscript.

Funding: This project was supported by a pilot award from the Mountain West CTR-IN Program, which is funded by a grant from the National Institute of General Medical Sciences of the National Institutes of Health: #1U54GM104944.

Institutional Review Board Statement: The Boise State University Human Subjects Institutional Review Board provided a review and approval of all study components (protocol number 186-SB21-118 approved on 7 June 2021). The study was conducted according to the guidelines of the Declaration of Helsinki.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author (luke.montrose@colostate.edu). Some restrictions to access apply as we intend to keep the participants and their facilities anonymous.

Acknowledgments: The authors are grateful for the support of the Montana Health Care Association and the Idaho Health Care Association.

Conflicts of Interest: The authors declare no conflicts of interest.

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